MINISTRY OF TECHNOLOGY

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

TECHNICAL NOTE No. 16

A Design for a Rotary Machine to Assess the Friction Sensitiveness of Explosives and Propellants

J.G. Rankine
H.C. Turner

WALTHAM ABBEY
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SUMMARY

A machine for assessing the friction sensitiveness of explosives and propellants has been designed to operate at velocities up to 30 ft/s (10 m/s), with a maximum dead load of 300 lb (150 kg). This has been accomplished by allowing the peripheral face of a metal disc to act on a flat metal plate, the load being applied pneumatically. The motion of the disc is effected by means of a flywheel striking a movable latch.

The prototype machine has successfully completed its initial tests. Load and velocity can be varied simply, and the time taken to perform the tests is less than with the modified pendulum machine upon which the action is based. Further proving trials will be needed before the use of the machine can be recommended as a standard test procedure.

Further copies of this technical note can be obtained from Mintech Reports Centre, Station Square House, St. Mary Cray, Orpington, Kent. BR5 3RE

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Reference: WAC/205/016

1. INTRODUCTION

This Establishment has been considering for a long period mechanical means of assessing the friction sensitiveness of explosives and propellants. The statutory mallet friction test is wholly manually operated and as such suffers from disadvantages. Various machines investigated in the past have proved unsuitable for a number of reasons; however, more recently, the Sensitiveness Section of the Explosives Branch has studied in some detail two others which have useful features. These were (a) the German BAM machine and (b) the RARDE Pendulum machine (for primary explosives) as modified by E Branch. Both of these employ surfaces which are initially at rest.

The original mode of operation of the pendulum machine was as shown in Fig. 1(a) where a sample of explosive is trapped between two anvils (1 and 2) under a known force, a pendulum then striking the top anvil and moving it in relation to the bottom anvil. As a result of studying the action of the BAM machine where a hemispherical ended surface (kept stationary) is subjected to friction with a moving flat surface, the mode of operation of the pendulum machine was changed as shown in Fig. 1(b). Here the explosive sample placed on anvil 4 is brought under a known load into contact with surface 3 which has a cylindrical surface ground to a known finish. The pendulum causes surface 3 to rotate. Trials with this modified apparatus led to the design parameters given in Section 4.

The rotary Friction Machine Fig. 1(c) - as the new one is to be called - uses the same bottom anvil (6) with the sample brought into contact with a disc (5) of known radial surface finish under a known load; the motion between 5 and 6 is imparted by means of a flywheel striking a moveable latch which causes rotation of 5 against 6.

2. DESCRIPTION OF MACHINE

The Rotary Friction Machine was designed to be a compact machine and in its present form occupies a floor space of approximately 2 ft 6 in x 3 ft 6 in x 4 ft 8 in high and could easily be designed as a bench mounted or even portable machine.

It consists of five main parts (Fig. 2):

(a) Flywheel
(b) Rotary Friction Head
(c) Thyristor controlled Electric Motor
(d) Compressed Air Loading System
(e) d.c. Solenoid Triggering Device

The machine needs only to be plugged into a 250 volt 50 cycle supply and attached to line compressed air or bottled compressed air not exceeding 300 lb/in^2 delivery.

/The .....

The flywheel speed of rotation is read from a direct mounted tachometer in rev/min and converted into friction velocity by the use of a chart. The tachometer can easily be recalibrated to read friction velocity direct.

The load applied to the anvil against the friction disc is by means of a compressed air cylinder. Again a chart is used to convert the gauge pressure in lb/in^2 to dead load on the anvil; this gauge also can be recalibrated to read dead load direct.

3. METHOD OF USE

The machine (Fig. 2) is used in the following manner.

A friction disc is placed on the friction drive head (b) with the drive pin engaged in one of the holes in the disc, the disc is then turned anti-clockwise until it reaches a pre-set stop. The anvil on which the explosive sample has been placed centrally is inserted into the anvil slide and onto the anvil table above the air cylinder (d). By rotating the air valve (Fig. 5(a)) to the up position the anvil is raised at a preset speed to contact the friction disc. The pressure regulator (Fig. 5(b)) is adjusted to give the required dead load on the explosive sample which is now pinched between the anvil and the friction disc.

The flywheel speed is set by the thyristor speed control and read from the tachometer to correspond with the friction velocity required.

The push button on the firing extension lead (Fig. 5(c)) is pressed, the machine is thus triggered and the friction disc will be rapidly driven through 50 degrees of arc approximately and the sensitivity test made.

To reset the machine for the next test, the air valve is rotated to the down position and the anvil will then return to its loading position when it can then be removed and a new anvil and sample inserted.

The friction disc is rotated to the next drive hole in the disc and before resetting in an anti-clockwise direction the safety tell-tale (Fig. 2) is checked to see that it has returned to the safe position.

4. DESIGN

At the commencement of design the following conditions (established by the system then in use) were given:

(1) The surface finish of the anvil and friction disc.
(2) The surface velocity at 30 ft/s.
(3) The maximum dead load between the anvil and friction plate at 300 lb.
(4) The diameter of the friction disc at $2\frac{3}{4}$ in.
(5) The friction disc should move from rest as quickly as possible and there should be no detectable change in velocity during its movement.

/It .....

It was decided that the machine would have a flywheel as the energy source to replace the swinging arm and a projection on the flywheel would strike the friction disc hence giving a similar system as that shown in Fig. 1(b).

The striking pitch circle of the flywheel was chosen arbitrarily at 12 in and by suitably shaping the striking surfaces of the flywheel striker and the friction head latch, the minimum of variation in velocity would occur during engagement.

With the flywheel striking circle at 12 in and the diameter of the friction disc striking circle at $2\frac{3}{4}$ in, for a periphery velocity of 30 ft/s of the friction disc this required the flywheel to revolve at 575 rev/min.

$$\text{rev/min} = \frac{(\text{Velocity in/s}) \times 60}{\pi \times (\text{P.C.D. Flywheel})}$$

$$= \frac{30 \times 12 \times 60}{\pi \times 12}$$

$$= \underline{575 \text{ approx.}}$$

The energy required in the flywheel was assessed from the swinging arm. The swinging arm had a 20 lb weight falling through a vertical height of 4 ft approx.

$\therefore$ the potential energy to be converted

$$= 20 \times 4 \text{ ft lb.}$$

$$= 80 \text{ ft lb.}$$

Hence if the flywheel possessed kinetic energy in excess of this it should at least be as effective as the swinging arm machine then in use.

The flywheel when running at 575 rev/min possesses approximately 250 ft lb. kinetic energy; this gives ample scope for experiments of sensitiveness at a much lower periphery velocity of the friction disc.

It was decided that the flywheel with a fixed striker (Fig. 2(a)) should run at any pre-set constant speed and a latch on the friction disc (Fig. 2(f)) could be engaged with the fixed striker on the flywheel, the latch being so timed by the flywheel that it will automatically engage and disengage without the need for the flywheel to be stopped for resetting.

A commercial variable speed drive was used to drive the flywheel, consisting of a $\frac{1}{4}$ hp electric motor (Fig. 2(c)) and the thyristor speed control requiring supply 240/250 V, 50 cycle, single phase; the flywheel speed is read direct from a tachometer.

/The .....

The method used to engage the friction disc assembly with the flywheel striker was to have a pivoting latch on the friction disc assembly pushed into the path of the striker on the flywheel by a small solenoid (Fig. 2(e)).

The pivoting latch is spring loaded in the disengaged position, the spring operating on a small diameter rod passing through the centre of the assembly the head of which appears on the friction disc side. The head of this rod acts as a safety indicator and must be in the disengaged position before attempting to reset the friction disc assembly.

At 575 rev/min the flywheel takes approximately 110 ms for one revolution and during this period the latch on the friction disc assembly has to be moved into position ready to be struck by the flywheel striker. This was achieved as follows.

A small 24 V dc solenoid is mounted on a bracket (Fig. 2(e)) with the push rod of the solenoid acting against the latch through the centre line of the friction disc assembly.

A micro-switch is mounted below the flywheel spindle and is operated by a cam fixed to the spindle; the switch is therefore pulsed once for every revolution of the flywheel.

A second micro-switch is mounted below the friction disc assembly and breaks the solenoid circuit at the end of the travel of the friction disc.

A capacitor is used to discharge into the solenoid giving a very fast action to the solenoid.

The circuit is shown in Fig. 3 and functions in the following manner.

When the circuit is first made live the capacitor charges. Pressing the push button P.B.1 energises the hold on relay R1 closing contacts R_1a and R_1b. With the next pulse of the flywheel switch SW.2 the hold on relay R2 is energised, contacts R_2a and R_2b close completing the circuit, the capacitor then discharges energising the solenoid. A small current passing through the resistor Res.11 maintains the solenoid in a hold on position until the circuit is broken by the rotation of the friction disc assembly opening the switch SW.1. The latch and solenoid is then returned by the spring to the disengaged position.

The cam operating the switch SW.2 can be rotated and secured in any position on the flywheel spindle, hence the solenoid can be timed to push the latch into position well before the approach of the fixed striker on the flywheel.

Compression of the explosive sample between the anvil and the friction disc is obtained from a double acting air cylinder mounted below the friction disc, the cylinder raising and lowering a small table on which the anvil sits.

The compressive load on the sample can be varied by a diaphragm pressure regulating valve controlling the air pressure fed to the air cylinder. The up and down movement of the cylinder is controlled by a rotary 4-way valve. The circuit is shown in Fig. 4.

/5. ....

5. CONCLUSIONS

Initial trials with the prototype machine has been successfully completed. The simplicity of setting the machine and the ease by which load and speed can be varied has greatly reduced the time taken to perform the sensitiveness tests as compared with similar tests on the modified pendulum machine.

Use has shown that improvements could be made. A lamp in circuit with the solenoid to indicate that the machine is safe to reset would be better than the tell-tale rod, which can be easily overlooked.

A scheme is already in hand to prevent the overrun of the friction disc (which varied according to load) such that the stroke of the friction disc can be controlled precisely under all conditions.

Further, the friction disc and anvil could be enclosed so that tests could be made in a controlled environment, e.g. one of low relative humidity or in an inert atmosphere.

Finally, it is to be emphasised that further proving trials will be needed before this machine can carry this Establishment's full recommendation for adoption as a standard test procedure for explosives.

/Conversion .....

Conversion of Imperial to Equivalent SI Units

Velocity	30 ft/c	=	9 m/s
Mass	20 lb	=	9.1 kg
	300 lb	=	136.1 kg
Length	$2\frac{3}{4}$ in	=	70 mm
	12 in	=	305 mm
	2 ft 6 in	=	0.8 m
	3 ft 6 in	=	1.1 m
	4 ft	=	1.2 m
	4 ft 8 in	=	1.4 m
Frequency	50 cycle	=	50 Hz
Pressure	300 lb/in^2	=	2.1 MN/m^2
Energy	80 ft/lb	=	108.5 J
	250 ft/lb	=	339 J
Power	$\frac{1}{4}$ hp	=	186.4 W

S. No. 104/70/BS

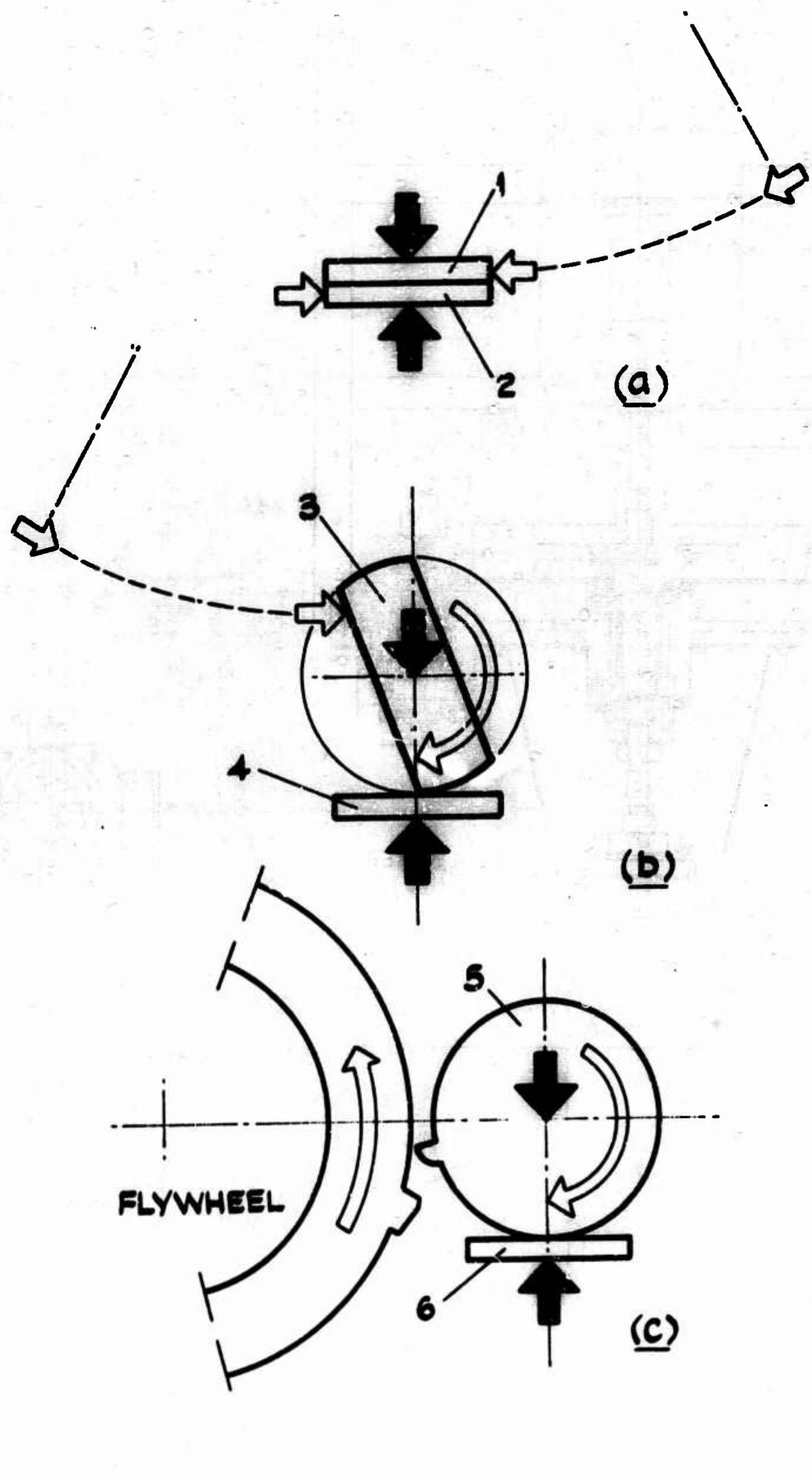


FIG. 1 PRINCIPLES OF OPERATION

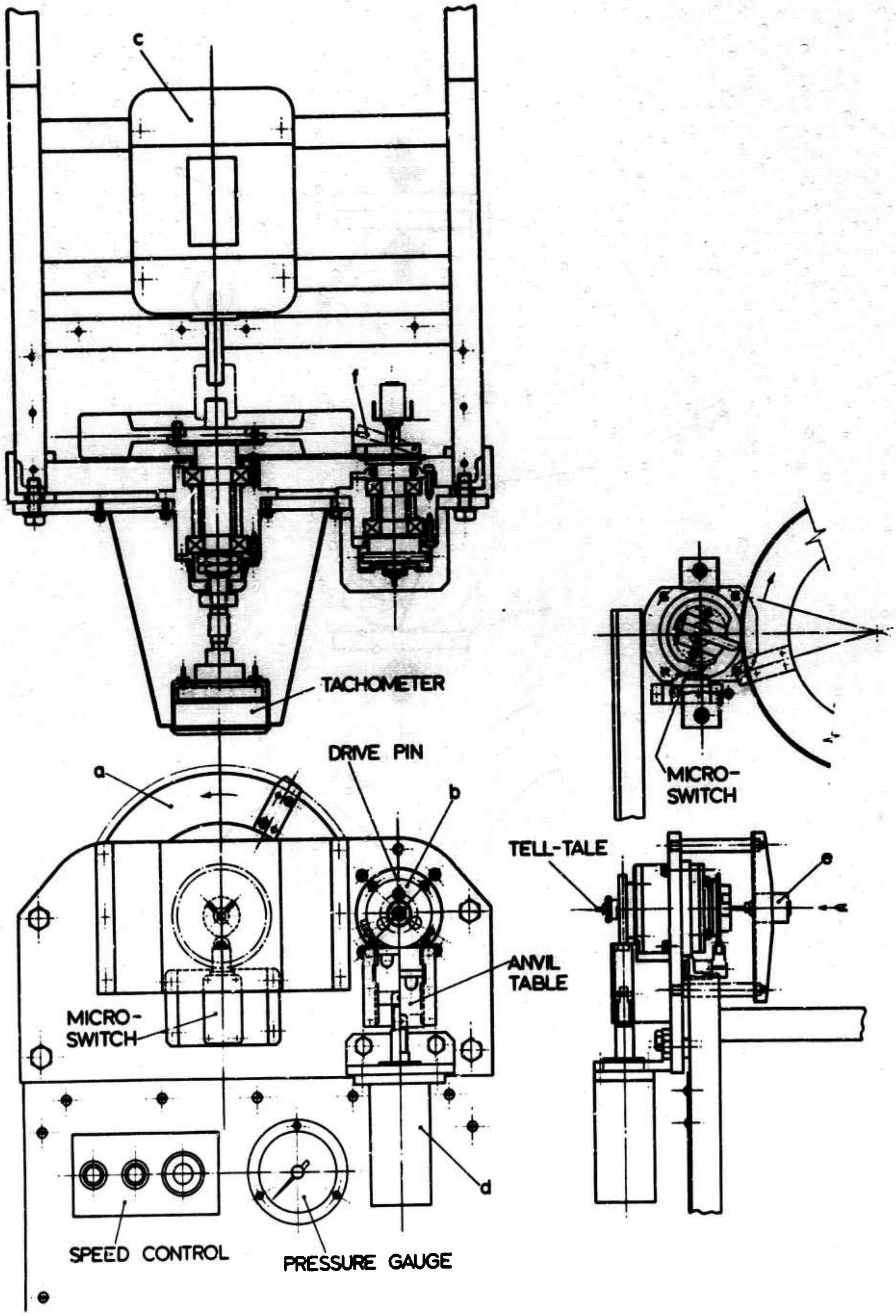
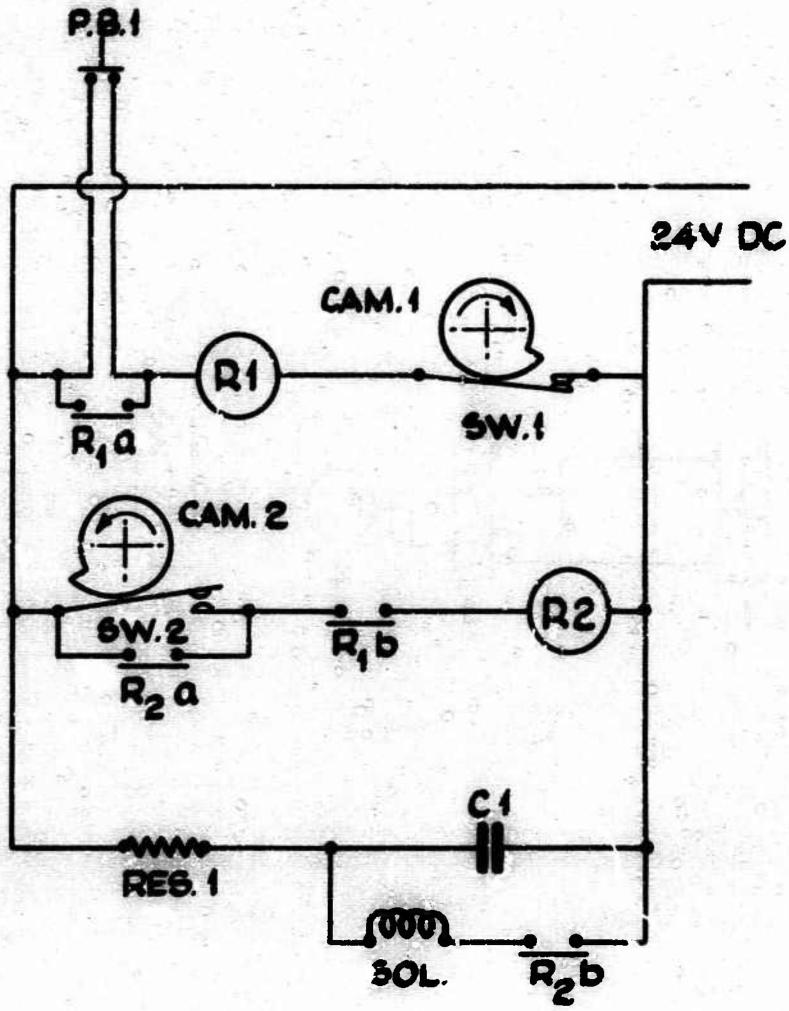
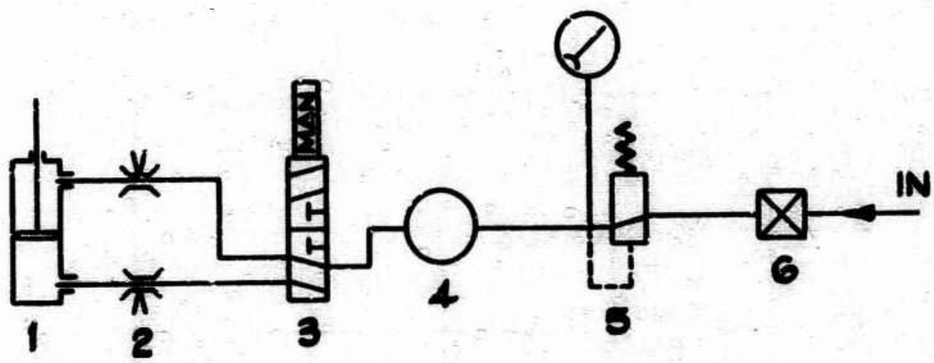


FIG.2 ROTARY FRICTION MACHINE



CAM. 1	STOP AND RESET CAM. (FRICTION HEAD)
CAM. 2	PULSE CAM (FYWHEEL)
SW. 1	MICRO SWITCH
SW. 2	MICRO SWITCH
R1	HOLD ON RELAY (2-CONTACT)
R2	HOLD ON RELAY (2-CONTACT)
C1	CAPACITOR
SOL.	SOLENOID
RES.1	SOLENOID (HOLD ON) RESISTANCE
P.B.1	PUSH BUTTON

FIG.3 TRIGGERING CIRCUIT



1. AIR CYLINDER (DOUBLE ACTING)
2. RESTRICTOR (VARIABLE)
3. ROTARY VALVE. 4-WAY
4. FILTER AND FOG LUBRICATOR
5. DIAPHRAGM PRESSURE REGULATOR AND GAUGE
6. STOP VALVE

FIG. 4 COMPRESSED AIR CIRCUIT

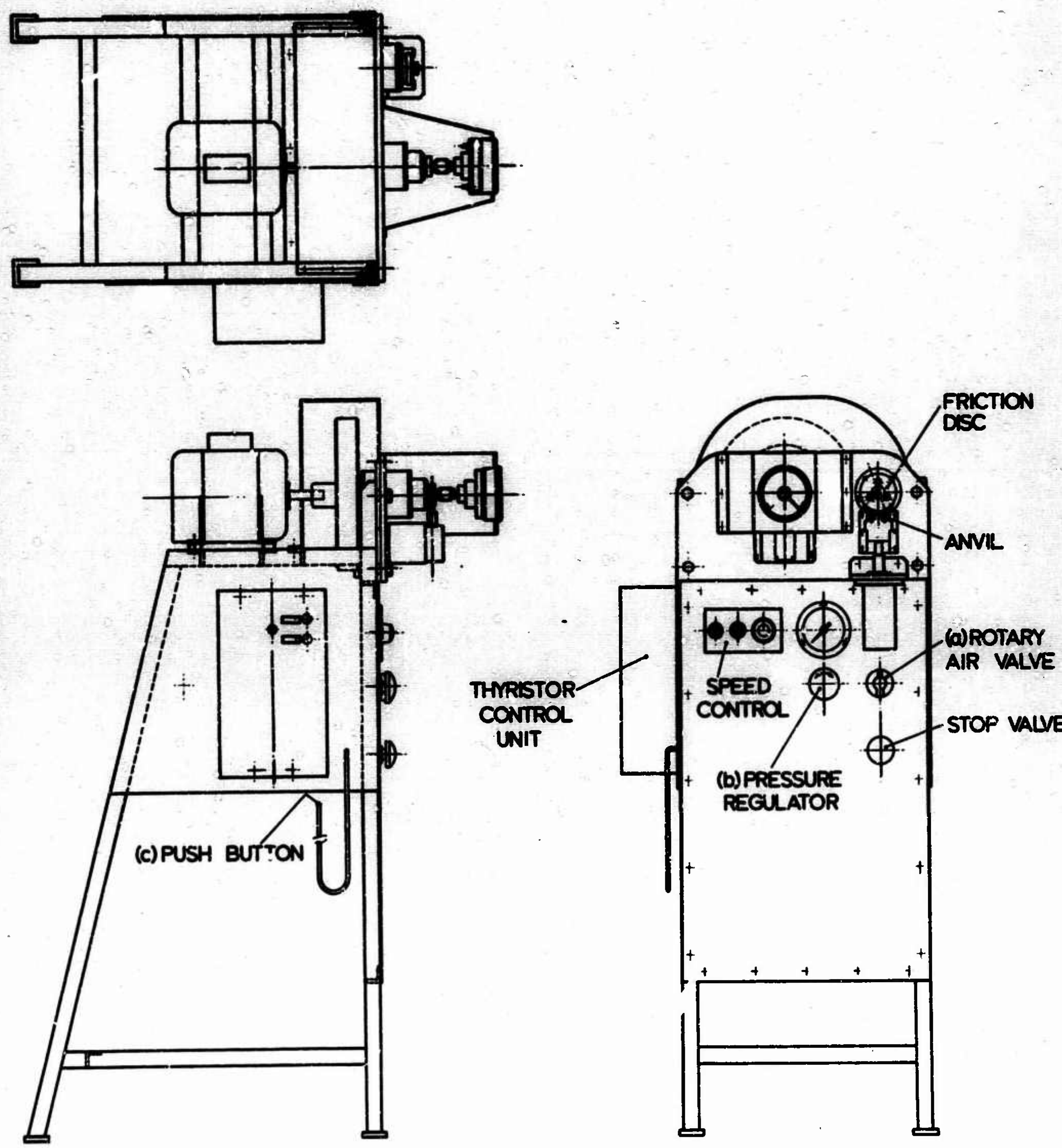


FIG.5 ROTARY FRICTION MACHINE